# THE WEATHER BUREAU EXHIBIT AT THE SESQUI-CENTENNIAL EXPOSITION.

Since a primary function of the Weather Bureau is to take observations of the weather elements and assemble them for the purpose of making weather forecasts, it is appropriate that the principal features of the exhibit be instrumental. The groupings of instrumental material naturally merge into and are inseparable from those which deal with weather and climate.

That a continuous picture of the weather might be obtained at all first-order stations of the bureau, it was necessary that something beyond the possibilities of human eye observations be devised. Hence the delicate instruments which continue to record the weather with ink impressions even while the observer sleeps.

The Daily Weather Map is the visible picture of simultaneous weather conditions over a large area. The glass weather map constitutes perhaps the most attractive feature of the exhibit. Upon receipt of the telegraphic messages conveying the results of the morning weather observations from all parts of the country, the data are assembled upon the glass map, so that, at its completion, the areas of fair or stormy, cool or warm weather, over the United States are well outlined. Hence the visitor from any portion of the country may gain a good idea of what the weather is "back home."

First in importance among the instruments are those which form the equipment of all principal observing stations. These include the quadruple register, wind vane, anemometer, rain and snow gages, sunshine recorder, maximum, minimum, wet and dry thermometers, barometers, barograph, and thermograph.

Quadruple register.--- The quadruple register is an office instrument which is connected electrically with the wind vane, anemometer, tipping-bucket rain gage, and sunshine recorder on the roof. As the weather causes certain actions on the part of the roof instruments, the actions are portrayed upon a register sheet wrapped about a cylinder which is turned by clockwork. The cylinder makes four complete turns in each 24 hours, and by means of a screw in its axis moves endwise so that the records are written continuously. The recording arms are equipped with suitable pens, or points, which draw or print the records by means of closures in the electrical contacts.

Wind-vane and anemometer support.--- A support is used on the roof of most first-order Weather Bureau stations in order that proper mounting and free-air exposure may be made for the anemometer and recording wind vane. Such a support is shown in the exhibit, the wind vane at the top, with the anemometer and attached cups carried on a cross-arm.

Wind vane and contacts.--- The wind vane is carried on roller bearings, and turns easily in even the lightest breeze. Beneath it in the support is a box which contains the actuating mechanism for printing on the

quadruple register sheet the direction shown by the wind vane. A contact plate in the box carries a series of four insulated springs and four rollers properly mounted and set on arms so that they move over cams mounted on the axis of the vane. The axial arms are set in the direction of the four cardinal points. As the vane turns, the contacting levers touch one or two of the mounted cams. Hence by electrical connections to the quadruple register the directions of the wind are printed on the sheet to eight points of the compass, the printing being done at intervals of a minute.

Anemometer and cups.--- The anemometer, or wind-measuring instrument, is actuated by the revolutions of the attached cups. Their movement is communicated. by means of gearing to a dial mechanism. The dial, which is fitted with ten mile-pins, makes one-tenth of a rotation for every mile of wind blowing across the cups. At the end of each mile a pin passes over a spring and closes the electrical circuit which connects it with the register. The velocity at any time of the day may thus be determined from the register sheet.

Indicating anemometer.--- This is an adaptation of the cup anemometer for determining the wind velocity without a register. When the button is pressed the number of closures per minute of the electric circuit by the anemometer contact, as counted by an observer watch in hand listening to the buzzer, corresponds to the velocity in miles per hour. The anemometer, exposed out-of-doors, is connected by a two-wire circuit to the indicator, within which is a 2-cell dry battery.

Tipping-bucket rain gage.--- The rain gage, which is connected electrically with the register, is mounted on a tripod, and has a circular collector 12 inches in diameter. The collected rain falls through a funnel into a two-compartment bucket, whence it is tipped into the bottom of the gage, and later drawn out for stick measurement, which is considered the authentic record. One-one-hundredth of an inch of rain as it is collected is exactly sufficient to fill one compartment of the bucket, whereupon it empties, thus causing the other compartment to come into position under the funnel. Each tipping of the bucket closes a circuit to the quadruple register, causing an off-set in the pen which draws the precipitation record.

Eight-inch rain gage and stick measurement of rain.--- At second-order or cooperative Weather Bureau stations, where no automatic records are made, the rain gage in common use has an 8-inch collector which allows the rainfall to drop through a funnel into a brass tube 20 inches long with a cross-section area one-tenth that of the collector. An inch of rain falling into the collector will thus be equivalent to 10 inches received in the tube. A graduated cedar measuring stick inserted in the tube gives the depth of rainfall to inches and tenths of inches. If more than two inches of rain falls, the extra amount goes into the overflow can, whence it may be poured into the tube at time of measurement.

Electrical sunshine recorder.--- This mechanism is composed of a glass tube, devoid of air, inside which is a small glass tube containing air, a small quantity of mercury, and sufficient alcohol to serve as a lubricant. The vaccum surrounding the inner tube insulates it from air temperature but not from radiation. The bulb of the inner tube is blackened to permit of ready absorption of heat when exposed to the sun. Such absorption heats the air in the black bulb more than it heats the air in the clear bulb and causes the mercury to rise in the tube until it covers two projecting wires, whereupon an electrical circuit is completed. This circuit closes once a minute through the clock connected with the quadruple register, and the sunshine record is then written upon the sheet.

The records of rain and sunshine are made by the same pen, but whereas that of rain is irregular, varying with the rate of fall, that of sunshine is regular, except when the sun is frequently obscured by passing clouds, and even then the record is unlikely to be confused with a precipitation record.

Mercurial barometers.---Changes in the pressure of the atmosphere are associated with all storm activities and with all important changes in the weather conditions. It has been found that the weight of a column of mercury about 30 inches high at sea level will balance the weight of a column of free air of the same diameter.

In the ordinary mercury barometer used by the Weather Bureau a tube of mercury rises from the center of a cistern containing the same element. The cistern has free access to the air, and the pressure changes therefore are readily communicated to it. With increased pressure, mercury is forced into the tube; with decreased pressure some of the mercury flows back into the cistern.

Aneroid barometers.---Another type of instrument used in measuring atmospheric pressure is the aneroid barometer in its varicus forms. The simple type consists of a metallic case with a dial on which a hand shows the pressure at a given time. The mechanism consists of a corrugated metal shell exhausted of air, placed near the bottom of the instrument. The shell expands or is flattened by the fall or rise in pressure. These changes are communicated to the hand by a suitable connecting chain, and linkage.

Pocket aneroid.---Small, portable aneroids are carried mainly by mountain travelers and for the purpose of indicating changes in pressure which accompany changes in elevation, or vice versa. In either case the mechanism is similar to that of the larger aneroid.

Aneroid barograph,---This instrument, an adaptation of the aneroid, is used for keeping a continuous record of the atmospheric pressure. Eight corrugated metallic shells, exhausted of air, and joined one above the other, provide the system of expansion and contraction. Each shell has a small steel spring inside to prevent possible entire collapse. By a system

of levers the shell movements are magnified and carried through a long arm to an attached pen. The pen rests lightly upon a record sheet wrapped about a cylinder which is turned by clockwork. The sheet allows of a 7-day record of pressure. The instrument is in common use at all major Weather Bureau stations.

Thermometers.---Thermometers of many kinds and adaptation are in use. Mercury, alcohol, and other fluids are employed as thermometric agents. The simple mercurial thermometer is the kind which tells us how warm or cold it is at any time. Then there are instruments from which we can tell the highest and the lowest temperature occurring during a given period. Others allow of a continuous automatic record of temperature, and still others through electrical devices and connections enable an observer in the office to tell the free-air temperature outside. The percentage of humidity of the air is also obtained from certain thermometric readings.

Exposed thermometer.---The common, or exposed, thermometer consists of a mercury-filled graduated glass tube with bulb mounted upon a graduated aluminum back.

Maximum thermometers.---The maximum thermometer varies little from the exposed except for a constriction at the base of the tube near the bulb. With rise in temperature the expanding mercury is forced out of the bulb through the constriction into the main channel of the bore. When the temperature falls, however, the simple weight of the mercury is insufficient to carry the additional mercury back into the bulb. Hence the top of the column shows the highest temperature for the desired period.

Minimum thermometer.---The actuating agent in the tube of the minimum thermometers is alcohol. A short index of black or dark-colored glass moves with the upper end of the alcohol column as the temperature falls. The index remains at the point indicating the lowest temperature, which may thus be read on the scale at the end of the index farthest from the bulb.

Thermometer support.---The maximum and minimum thermometers are mounted nearly horizontally upon a suitable support, the maximum being below the minimum, and both free to allow of independent movement. The maximum thermometers must be lowered carefully to a vertical position to be read. Owing to the restriction in its bore, the instrument must be whirled more or less violently upon its support to "set" it after a reading. Some of the mercury in the tube is thus forced back into the bulb, and the reading then becomes that of the current temperature. Setting of the minimum thermometer is accomplished by raising it to a vertical position, bulb uppermost, whereupon the index will fall to the end of the alcohol column. After the setting, all thermometers having the same exposure should read alike.

Thermograph.---This is the temperature writer, with actuating mechanism. The record sheet is wound about a cylinder rotated by clockwork. In this autographic thermometer a flattened, curved metallic tube contains the alcohol. Increase in heat causes the curved tube to straighten slightly, and reduction of heat causes a greater curvature. The shortening or lengthen-

ing of the tube moves a linkage bar connected with the pen arm. The measure of expansion and contraction is thus recorded on the properly ruled sheet as degrees of temperature. Thermographs in actual service are exposed with the other thermometers in instrument shelters to obtain free-air temperatures. The accuracy of the records is checked by frequent eye observations of the other thermometers.

Tele-thermoscope.---This is an office instrument which is connected through a 3-wire electrical circuit with a coil of fine nickel wire in the instrument shelter on the roof. The indicator contains a modified wheatstone bridge which measures the resistance offered by the nickel coil to the passage of an electrical current. This resistance varies with the temperature, and is indicated on a temperature scale. To obtain the temperature a button in the instrument is pressed, and a knob turned until a galvanometer needle is balanced. The correct reading is then indicated on the scale.

Distance recording thermograph.---This instrument provides an indoor automatic record of outside temperatures. The thermometric bulb is installed in the instrument shelter and connected with the recorder by a capillary copper tube about 75 feet long.

Whirled psychrometers.---As previously mentioned, the simple thermometer is also used for obtaining the humidity of the air. Two exactly similar thermometers are mounted upon the arms of the whirling device. The bulb of one is wrapped with a strip of thin cloth. For the sake of convenience the thermometers are then called, respectively, the dry and the wet-bulb thermometers. When an observation is to be taken, the wet-bulb is moistened in water. The thermometers are then whirled rapidly by turning the crank. Rapid evaporation from the wet-bulb takes place, accompanied by cooling. When, by frequent observations it is seen that the wet bulb has cooled in the greatest possible degree, the two thermometers are read. From the difference between the two readings, the moisture content of the air may be found through the use of appropriate tables.

Sling psychrometer.---This is a combination of wet and dry thermometers, in which the whirling is accomplished by means of a handle and attached linkage. It is used where the fixed apparatus is either unavailable, or not desirable.

Hair hygrometer.---Another type of instrument from which measurements of atmospheric humidity are obtained is the hair hygrometer. The ends of a small bundle of human hairs, from which the oil has been removed, are held firmly between two parts of the mechanism back of the dial plate, which latter is graduated into percentages of relative humidity. Since hairs change in length with change in the moisture content of the atmosphere, the value of this change has been so applied to the linkage which carries the hand over the dial, that the proper humidity in percentage of the possible is constantly pointed out.

Hair hygrograph.---A utilization of the expansion and contraction quality in hair is further shown in the hygrograph, whereby an unbroken record of humidity is traced upon a sheet wound about a cylinder, which is rotated by an inclosed clock. The motion of the shortening or the lengthening of the hairs is transmitted to the pen-arm through the mechanism.

Cooperative observers' equipment.---Aside from the observations made by its major stations, the Weather Bureau collects temperature, precipitation, and weather data from about 4500 cooperative stations in the United States, the West Indies, and Alaska. The equipment consists of an instrument shelter, maximum and minimum thermometers, and a rain gage. The gage is of the 8-inch pattern, and has been previously described.

Instrument shelter.---All shelters used in connection with the proper exposure of thermometers are so built as to exclude the sunshine, but permit of free circulation of the air. Those used by cooperative observers are similar to the shelters used at regular stations, but are smaller, since they must house only the maximum and minimum thermometer set upon their supports. The highest and lowest temperature readings are the only ones required from the secondary stations.

## SNOW MEASUREMENTS.

Snow stake.---The depth of snow on the ground as well as the depth of the individual snow fall may easily be obtained by a graduated yard stick. In the mountain regions, particularly of the West, where heavy snowfalls occur, snow stakes are extensively employed. The stake is made of 1 1/4 inch cypress bolted to a galvanized-iron angle, the end of which is pointed so as to be driven easily into the ground, where it is held upright by three guy wires. The stakes have numbers, 1, 2, 3, etc. at 10-inch intervals. Thus, the figure 9 would appear on the stake 90 inches above the ground.

Snow density tube and scale.--- The tube, which is made of light-weight metal, is used largely in remote regions where snow surveys are required to determine the water content in the snow layer over a great watershed. The observer must frequently penetrate to such rugged, remote regions that it is necessary to carry his equipment about with him on snowshoes. The tube is forced vertically through the snow to the ground, then withdrawn with a snow sample. Tube and contents are then weighed by a spring balance which gives the equivalent of the snow layer in inches and tenths of water.

Shielded snow and rain gage.---This type of gage is adapted to catching rain, but more especially snow, in windy locations, generally in remote parts of the western mountain regions. It is built of galvanized-iron. The collector is 10.86 inches in diameter and with an inside depth of 34 inches, the whole carried on an adjustable support from which it can be removed in order to measure the precipitation. The measurement is done by weighing on a special spring balance, the dial of which is graduated to read in inches and hundredths. The gage in the exhibit is a model, and is one-fifth of the regular size.

Fluid-dram rain and snow gage.---This gage has a collector of different size from the others, in being 5.36 inches in diameter so that each hundredth of an inch of fall equals one-third dram. Since a graduated glass may be purchased locally, and the gage may be fabricated by a good metal worker, a person interested in precipitation measurements may readily obtain one.

Aerological equipment.---At stations of the Weather Bureau an equipment is maintained for exploring the atmosphere by means of kites or sounding balloons, with self-registering instruments attached. The kites are sent out attached to fine piano wire which is controlled by a reel within a reel-house, which may be oriented as desired.

Kite meteorograph.---The meteorograph is an unusually light weight instrument, weighing complete with cover, some less than 2 1/2 pounds. It registers four weather elements, namely, pressure, temperature, wind velocity, and relative humidity. The wind velocity is measured by a fan-type anemometer placed in the windward end of the screening tube. The other individual mechanisms are exposed at convenient points, and all are mechanically connected with their respective recording pens. Since the elevation of the kite is constantly known, an examination of the record sheet shows the conditions at the given time and elevation.

Sounding balloon.---The balloon is intended for exploring the atmosphere at heights not otherwise attainable. It is held secure within a light wicker cage. As the balloon rises it is watched by theodolite and timed so that its direction of movement and height to a considerable elevation may be known. At a height which varies with the atmospheric conditions, etc. the balloon bursts, and the cage falls to the ground. The usual height of bursting is about seven miles, but the record height is nearly 20 miles. Owing to the protection of the cage and the parachute action of cloth streamers, the meteorograph generally escapes injury. The finder is requested to return the apparatus to the Weather Bureau.

Nephoscope.---An instrument which is used in following the movement of a cloud by observing its reflection in a black mirror, is the nephoscope. It was designed for the determination of cloud directions and velocities. The eye-piece stand is adjusted about the mirror until the observer, looking through the eye-piece, sees the cloud image reflected at the center, whereupon he follows its direction and notes where the image leaves the mirror. The apparent cloud velocity is found by taking the number of millimeters traversed by the cloud shadow across the mirror and dividing by the number of second occupied in the movement.

River and flood service.---The river work of the bureau carries its own peculiar type of instruments. There is the river gage where, by eye observation, the rise or fall of the water may be seen. At other river observing stations a float in a still-well connects electrically with an office register and gives this information. The office instrument is known as the indicator or recorder.

Marvin water stage register.---Although the river may be at a considerable distance from the office, yet the information of its rise and fall is recorded automatically, each tenth of a foot of change in the still-well releasing the clockwork of the transmitter, so that an electrical mercurial switch tilts, thus operating the indicator magnet of the register. The dial hand on the indicator shows the river stage, and the arrow point shows whether the river is rising or falling.

Orchard heating.---In certain parts of the country orchards are protected from frost damage by means of oil heaters, of which several types are in use, but only one of which, a tall-stack type, is exhibited. Hot gases arising from the heater and radiation from the red-hot stack change the temperature of the outer air appreciably. Several pictures on this subject are shown by the projector. For special information, see Farmers' Bulletin No. 1096: "Frost and the prevention of damage by it."

Storm-warning towers, flags and lanterns.---About 400 storm-warning stations displaying flags by day and lanterns by night, for the benefit of navigation, are in operation on the Great Lakes, and the Atlantic, Gulf and Pacific coasts. All stations hoist flags in advance of approaching winds dangerous to shipping, and for night displays most of them in addition are provided with lanterns installed on steel towers, a model of which is here shown. Explanation of the warnings will be found on the cards nearby. A full-sized electric lantern is also on exhibit.

Automatic projector.---A brief description has been given of the various instruments and other devices generally or especially in use by the Weather Bureau, and any one desiring further information may generally find it by applying to the attendant.

The display of pictures and pointed statements in connection with concrete duties and equipments often serve better to illustrate special items and the uses to which certain mechanisms are put than can otherwise be done. In the projector, therefore, some 72 slides are shown upon a screen, and a fairly comprehensive idea as to the many and varied duties performed by the bureau may be obtained.

Multiplex frames.---An additional source of pictorial information, as well as a valuable series of weather charts, is the display on the multiplex frames in this exhibit.

Among the charts are some which show certain average conditions of weather over the world, though most of them show average and special conditions for the United States only. Precipitation, temperature, frost, humidity, sunshine, cloudiness, and daily weather, are featured.

Attention is especially paid through the pictures to the various phenomena of weather. There are views of cloudland; of storms and their effects, as related to floods, hurricanes, tornadoes, hail, snow, and sleet; besides other scenes of interest which are disclosed in this chart and picture book.

Lightning booth.---Increasing attention is being devoted to the protection of buildings from lightning through proper rodding. The lightning booth, while designed to present an object lesson showing a result of protection and nonprotection, is sufficiently spectacular to awaken interest. One sees the lightning, hears the thunder, and sees the glare of the burning building.

Publications of the U. S. Weather Bureau.---Sample copies of annual reports, monthly weather reviews, and supplements, circulars, bulletins, Climatological Data, and miscellaneous publications.

Publications for which a charge is made must be obtained by addressing the Superintendent of Documents, Government Printing Office, Washington, D. C.